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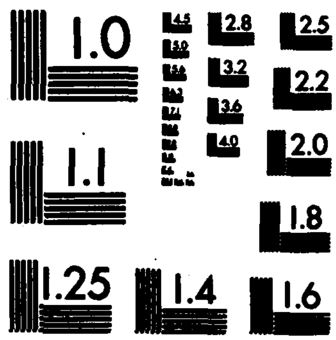

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AD-A147 756

An Auroral X Ray Imaging Spectrometer

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30 September 1984

APPROVED FOR PUBLIC RELEASE;
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Prepared for

SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
P.O. Box 92960, Worldway Postal Center
Los Angeles, Calif. 90009

84 11 14 010

This report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-83-C-0084 with the Space Division, P.O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009. It was reviewed and approved for The Aerospace Corporation by H. R. Rugge, Director, Space Sciences Laboratory. 1st Lt Douglas R. Case, SD/YCM, was the Air Force Project Officer.

This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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DISCUSSION OF THE EXPERIMENT

The Special Sensor B/Aerospace (SSB/A), flown on the USAF-DMSP-F6 satellite, is a two-scanning-head X-ray spectrometer designed to measure X-rays in the energy range 1.8 keV to > 100 keV emanating from the Earth's atmosphere.* This instrument is a second generation X-ray spectrometer[1] capable of determining the X-ray energy spectrum of any source within a 70 km × 130 km pixel size from limb-to-limb of the earth.

The SSB/A instrument was launched aboard the DMSP-F6 satellite on December 20, 1982 into a dusk-dawn sun-synchronous polar orbit at an altitude of 830 km. In addition to a primary visible imager designed to measure near-infrared wavelength emissions with a spatial resolution of a few km, other special sensors aboard include precipitating electron and ion electrostatic analyzers (SSJ/4) capable of measuring high-latitude auroral fluxes from 0.03 to 30 keV every second. With these instruments auroral phenomena can be monitored over each polar region every 50 minutes. The visible imagery and the precipitating charged particle data are archived through the NOAA World Data Center and are available by subscription.

*Full paper available as an Aerospace Corporation Technical Report (TR-0084(4940-06)-1),"Description of the SSB/A X-Ray Spectrometer," W. A. Kolasinski and P. F. Mizera.

The SSB/A instrument is composed of 5 principal components: The high-energy X-ray sensor, the low-energy X-ray sensor, a hydrogen Lyman-alpha sensor, background monitors, and the motor drives and programmer unit. All relevant information is sent through a data processing unit and telemetered to ground stations.

The mass of the instrument is 14.5 kg and consumes 9 watts of power when fully operating. Among some of the unique features of the X-ray spectrometer are the two scanning heads which rotate across a 110° arc with opposite angular velocities. A complete limb to limb scan takes 10 seconds, with a complete data readout each second.

The high-energy X-ray scanning head contained 3 cadmium telluride semiconducting detectors approximately 1 cm^2 by 0.2 cm thick, each with anticoincident scintillator shields. The field of view of each detector is 14° and symmetrical about the telescope axis. Three differential energy channels were obtained from thresholds set at 15, 30, 60, and 100 keV. The cadmium telluride detectors operate most efficiently below ~ 0°C, a temperature maintained by passive thermal control.

The low-energy X-ray scanning head contains a proportional gas counter with a three-atmosphere mixture of argon and xenon with a CO_2 quench. The 0.01-cm-thick beryllium windows set the low-energy X-ray threshold at approximately 1.8 keV. The effective area of the detector is 3.7 cm^2 and the entrance collimator subtended a 5° (in track) by 10° (cross-track) field of view (full width half maximum intensity).

Two methods are employed to reduce the background signals from the low energy sensor. A broom or bending magnet is mounted at the entrance collimator to prevent electrons from entering the collimator and producing local bremsstrahlung X rays. The second method employs the fast rise time of the proportional counter pulse in order to discriminate X rays from energetic penetrating charged particles. The results of these background suppression techniques are evident in the orbital data. For example, over the polar caps of the Earth, the background rate is less than 1 count/sec/channel and remains low even when the instrument views magnetic field lines that contain auroral electrons.

The major sources of background on orbit are (1) energetic trapped electrons near the low-latitude boundary of the aurora and (2) auroral electrons impinging on a sun shield used for the prime visible imager. The energetic electrons produce X rays with energies up to a few hundred keV when they stop in the spacecraft structure. Although the proportional counter was shielded with a high-atomic-number material (tantalum, Z = 73), the energetic X-ray background is too intense in the radiation belts to make useful measurements. The second source of local X rays is due to a sun shield umbrella structure that came into the field of view of the X-ray scanner approximately 20% of the time. When auroral electrons interact with the sun shield they produce an X-ray background that is impossible to distinguish from X rays emanating from the Earth. Background from solar X rays is not significant except during severe solar flares.

Remote sensing of X rays produced by auroral electrons precipitating into the Earth's atmosphere has many applications. Some of these include the ability to predict radiowave propagation deficiencies by monitoring enhanced ionization and the capability of producing high-latitude electrical conductivity profiles for magnetospheric models under both sunlit and dark conditions.

Figure 1 shows a sequence of north polar X-ray images acquired by DMSP-F6 on January 16, 1983. The satellite crosses the dawn local time aurora at the bottom of each image and proceeds across the polar cap to the dusk sector. The sun is to the right. From an altitude of ~ 830 km, the image covers approximately 50% of the polar region above 70° latitude and approximately 35% above 60° latitude. The total X-ray fluence is plotted in Figure 1, although spectral information is available also.

The first polar crossing occurred near 11:49 Universal Time (UT) and is shown in the top left hand corner of Figure 1. The satellite crossed the center of Canada near 06 hours local time. The auroral activity extended from Fort Churchill on Hudson Bay up to the northern border of the northwest territories. On the left side of the image, the aurora extended out from local midnight almost up to 80° north latitude.

The next northern crossing almost paralleled the western border of Canada. The aurora, situated in the local midnight to local dawn time sector, crosses the southern border of Alaska. Significant auroral activity is apparent even at the highest latitudes.

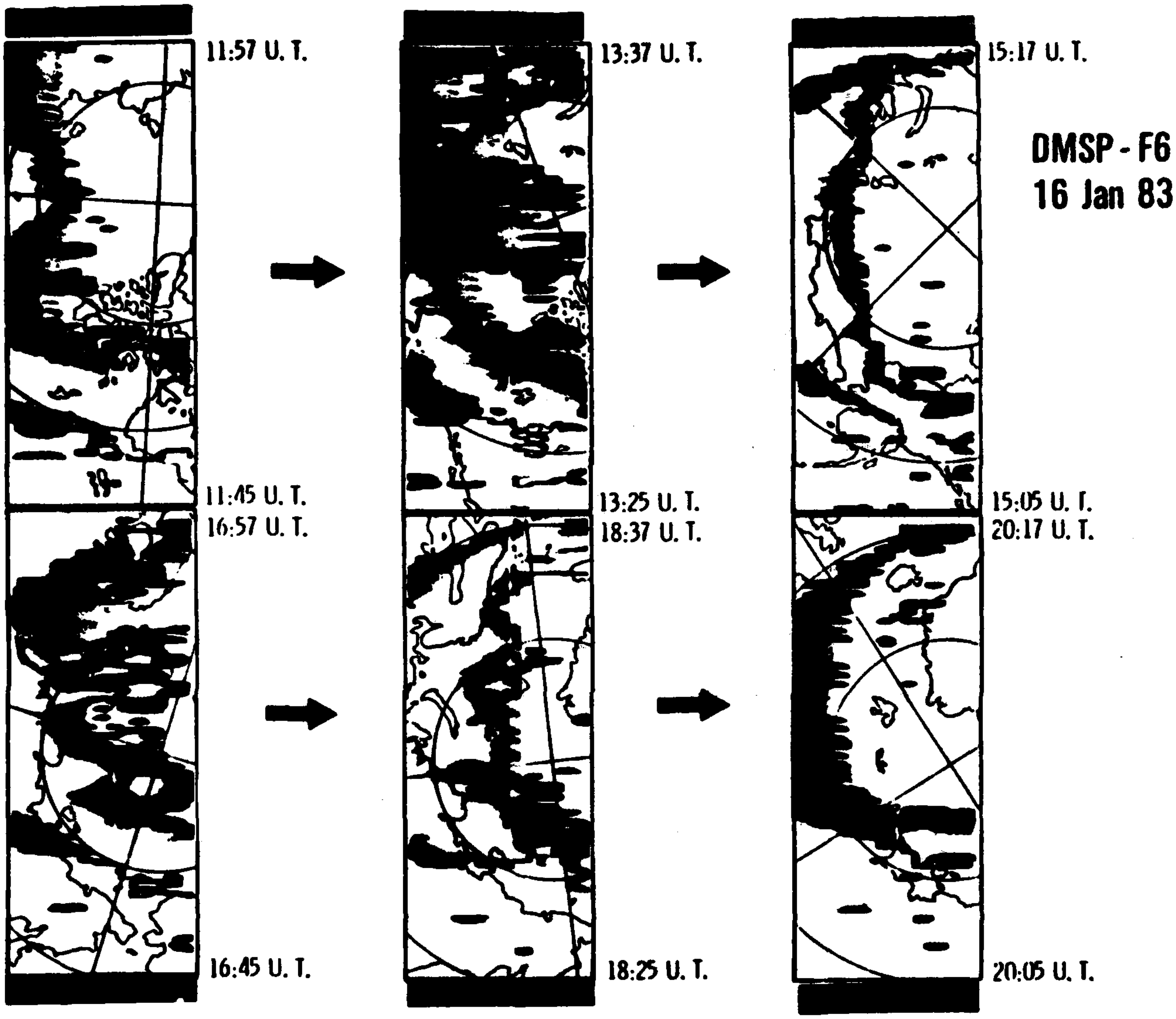

Fig. 1. Six Northern Polar X-Ray Images

The third in this series of northern polar crossings passed through the center of Alaska in the dawn local time sector. The activity is confined to the auroral oval with a spatial width of ~ 200 km and little activity over the polar cap. The dusk aurora extends around to the Scandinavian countries.

Near 16:51 UT, the satellite crossed the western Aleutian Islands at dawn and the auroral activity has moved to the north of Alaska and well onto the polar cap. The dusk activity is weak and is located on the northern border of the Scandinavian countries. On the next northern polar orbit, the auroral activity intensifies near local midnight near the Kara Sea at the northern border of Russia.

The last image shows the aurora near 20:11 UT and illustrates how the global auroral activity had decreased. Weak activity encircles the northern border of Greenland.

Examples of X-ray images acquired by the SSB/A instrument aboard the DMSP-F6 satellite show it is possible to determine auroral boundaries with spatial resolution of ~ 100 km. Methods of inferring spectra of precipitating auroral electrons from the X-ray data provided by the SSB/A spectrometer have been developed. Apart from providing a measure of auroral activity in the form of energy input to the atmosphere, these spectra allow calculations of altitude-density profiles of electrons in the ionosphere and the determination of ionospheric conductivities.[2] Remote sensing of the ionosphere has been used to compare the upper D and E profiles of the ionosphere inferred from X-rays with those measured by ground-based radar measurements.[3] Studies are currently underway to compare images of auroral X-ray production with cosmic noise absorption events taken by riometers at the South Pole.

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LABORATORY OPERATIONS

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Space Sciences Laboratory: Atmospheric and ionospheric physics, radiation from the atmosphere, density and composition of the upper atmosphere, aurorae and airglow; magnetospheric physics, cosmic rays, generation and propagation of plasma waves in the magnetosphere; solar physics, infrared astronomy; the effects of nuclear explosions, magnetic storms, and solar activity on the earth's atmosphere, ionosphere, and magnetosphere; the effects of optical, electromagnetic, and particulate radiations in space on space systems.

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